HUMAN FACTORS ENGINEERING

A Self-Paced Text
Lessons 1-5

Ruth Brogan
Jerry Hedge
Kevin McElory
Judah Katznelson

US ARMY HUMAN ENGINEERING LABORATORY
PACIFIC MISSILE TEST CENTER

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This report presents

the trainee

FOREWORD

You are about to begin ~~a~~ self-paced, programmed course on human factors engineering. The main objectives of the course are to provide ~~you~~ with a basic understanding of human factors engineering and its application to equipment/system design.

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In addition, the material is presented in a lighter, less formal style than an ordinary text in the hope that a little humor will result. You will meet some characters in the course such as LT I. A. Eager and CPT B. Smart. After a brief acquaintance with these characters, you will begin to identify elements of behavior and attitudes which you yourself may have or display. Intelligence and eagerness are key elements in doing a good job, but they often drive us in the direction of "just using common sense." You will learn that human factors engineering and good design are more than common sense. However, you will learn that the <u>application</u> of human factors engineering certainly makes good sense.

With these thoughts in mind, we think the course objectives will be met, and that you will enjoy the experience.

One final note; you will find yourself jumping from page to page. This may be irritating, at first, but remember this is a programmed text, and our job is to lead you through material without being present. This jumping from page to page will help in this process and provides important feedback even when you choose the wrong answer by providing material and a rationale which will make it a positive learning experience. In addition, it helps prevent boredom and makes you work a little to get your answers.

cont'd

[illegible] in a User's guide to Programmed Instruction

HUMAN FACTORS ENGINEERING

cont'd pg 10

LESSON 1: WELCOME TO HUMAN FACTORS ENGINEERING

How To Use This Book

How long has it been since you learned something by sitting down with an instructor and mastering a topic through the interchange of questions and answers? Most of us seem to learn best this way, but modern demands for proficient instructors and high trainee loads have resulted in large classrooms, which make a close teacher-student relationship impossible. We are attempting to recapture this valuable person-to-person relationship. To do this, we are using the technique of programmed instruction, a technique proved to teach things better and help you remember the things that you have learned.

As you go through this programmed book, you will encounter the same interaction you would find if you were the only student of an instructor. One of the first things you will notice is that this book is different from any other book you have used. You will be given a unit of information, and the instructors (authors) will then ask you a question to determine if they have gotten the point across. When you select the answer that you think is correct, you will be directed to a page that is responsive to your answer and to your rate of learning. Each person goes through the material in a different order and in a different amount of time. This 'scrambled' order is tailor-made for your particular learning needs. Because of this, you will not be able to 'skim' pages as with a regular book.

To summarize the instructions: Read the material on a page and digest it. Then answer the question presented at the conclusion of that portion and turn to the page that is indicated directly after the answer you have selected. Sometimes, you will be directed to go to another page without being asked a question. The program will work only if you follow these directions. Because programmed instruction results in a large number of pages, the 40 lessons of your Human Factors Engineering Course will be presented in blocks of 5 lessons each. The Table of Contents page of your text will give you the starting page of each lesson.

Remember, this form of instruction is not a test; it is a method designed to teach you what you need to know about human factors engineering.

Now, a decision:

1. If you want to learn this material from a conventional technical textbook, go to your technical library.

2. If you want to learn by this programmed method, turn to Page 13.

WHAT ARE YOU DOING HERE?

This is Page 2. The instructions told you to turn to Page 13, not to the next page!

Remember, you will be reading this book in a way that is different from what you are used to. Follow the instructions and turn to the page number that is either beside the answer you select or indicated at the bottom of the page.

Let's sharpen up and start again! Turn to Page 13 and follow instructions.

From Page 15

(4) You haven't read closely enough. All of these points are valid, but Taylor touched on only one. Return to Page 15.

From Page 39

(4) Nice try, but your answer was only partially correct. Human Factors Engineering deals with both machines and physical environments, but it also can and does benefit people when they interact with their personal tools and equipment. Furthermore, human factors engineers are also primarily concerned with human work performance as a measure of effective functioning. Go back to Page 39 and try again.

From Page 13

(2) Personnel do have to be selected, but not before you determine what they have to do in the system. Go back to Page 13 and try again.

From Page 36

(2) You indicated that re-evaluating the man-machine division of assignments would be the first step if it were determined that man was incapable of performing a given task. You are correct. The rearrangement of assignments may result in higher cost or lower maintainability, but such trade-offs must be expected to take place.

Coping with trade-off analyses should be expected throughout the system development process. After all, if everything in every design conception fell neatly into place, there would be a lot of unemployed human engineers and little call for their analytic expertise. The situation we have discussed, where either man is physically incapable of performing a given task, or it is economically infeasible to adapt the machine to man's capabilities, does not signal the end to the man-machine interface scenario. Rather, the role of such cues is to indicate to the human engineer that further investigation is needed to define new and alternative routes to balance man-machine capabilities so that the same objectives for the system are realized.

Also in your supplement is Figure 2-1 which represents the man-machine system. As you can see, this figure displays input data reaching the person in the form of displays of various types. After processing by the human, a control is activated which, in turn, results in a systems output. This figure represents the essence of Human Factors Engineering.

Well, you now have a better understanding of what Human Factors Engineering is all about. We also hope that you see how Human Factors Engineering fits into systems design. Unlike I. M. Eager, you, perhaps having had your thumb sliced by a beer or cola can tab or two, probably realize the importance of Human Factors in system design and implementation.

Most of this course in Human Factors Engineering will deal with man in a system which is job-related. A good deal of the material to be presented will be related to military systems. However, we think it is important for you to realize that human factors engineers are also instrumental in the design of many other systems in which people operate.

(Go on to the next page)

From Page 4

For example, not all military personnel drive around in tanks or pilot aircraft--a great deal of the people are employed in offices. All people have some type of living quarters. Human factors engineers are also concerned with these types of systems. Architectural design teams take into account the behavior and attitudes of people when designing work places and living environments. Concepts such as personal space (the space immediately surrounding an individual), social interaction, and attractiveness are all used in designing an area which is functionally efficient as well as pleasing to be in.

A newer idea of human factors endeavor has to do with the application of human factors principles in service and other related facilities. In the area of urban public transportation, human factors considerations have been focused on interior design of the vehicles as well as the station areas, convenience and mobility, safety and security, social factors, and interaction of the system with the environment in areas such as congestion and pollution. Other service-related facilities that have benefited from human factors involvement are the health and personal safety services. The use of documented body measurements and functions have resulted in improved surgical instruments. Human factors principles used in the development of highway signs have improved their readability and in so doing, increased the safety of those using the roadway. There are numerous other examples as well.

Well, you get the idea. There is a vast range of situations and systems which fall within the domain of the human factors specialist. Indeed, it is an area of study and application which interests many and helps almost everyone.

Smart told I. M. everything, just as we have related it to you. However, I. M. still wasn't convinced. He and Smart began to discuss their varying points of view. Smart decided to bring his big guns to bear in order to help I. M. realize the truth of the matter. He decided to relate to Fager some of the dangerous consequences of not considering the human's capabilities in the design of a system.

This ends Lesson 2, but... coming soon is Lesson 3. Tune in again for a lesson on tragic mistakes and positive outcomes. Turn to Page 50 to start Lessen 3.

From Page 32

(1) Right, these are all examples of adjustment error. The most common error of this type which was made was in turning the fuel selector switch so that it was halfway between two tanks. When this occurred the fuel could not flow from either tank. Again, serious consequences ensued.

The other types of errors included such things as inability to reach the control, unintentional activation of the control, and reversal errors. For example, one pilot did not use his pre-flight checklist because he was in a hurry. He subsequently forgot to remove the external control lock which kept the control surfaces from moving. As a result, once he was airborne, he couldn't control roll and pitch and the aircraft crashed, killing all those on board.

The findings of Fitts and Jones were important because they led to improvements in aircraft design. Design methodology was also improved to give adequate consideration to operator characteristics in design. Often a design team performs its job extremely well, but doesn't take into account the human capabilities that are required in operating the system. Each specialty team may make an erroneous assumption that someone else has accounted for the human component, or may just assume that the human can handle whatever they build. Of course, we know that last assumption is incorrect, don't we? As a result of the Fitts and Jones study, design teams were required to design equipment to accommodate optimally the human operator as fully as possible.

Such design programs helped equipment to be designed which took into account the typical responses of people. These typical responses are called population stereotypes. Now, which of the examples given below is an example of a population stereotype?

(1) Reading printed material from right to left. Turn to Page 27.
(2) Stopping on a red and starting on a green signal. Turn to Page 30.
(3) Both of these are stereotypes. Turn to Page 35.

- -

From Page 42

(1) You indicated that you felt Human Factors Engineering deals with systems which have no automation. You're limiting the role that Human Factors Engineering plays. Return to Page 42.

- -

From Page 40

(2) You indicated that Human Factors Engineering is just common sense. Are you a son of I. M. Eager? While common sense is involved anytime problems are found and their solutions sought, Human Factors Engineering is a rigorous scientific discipline. We hope this course will demonstrate to you just how important it is to test one's common sense judgements. Too often they alone are inadequate. Return to Page 40 and choose again.

- -

From Page 30

(3) We wish it were so. Go back and choose a higher value from Page 30.

- -

From Page 80

(1) Correct. Well over 1,000 deficiencies were cited.

As a result of reports such as these, the Navy has now begun to require human factors input to ships acquisition and design systems. It is expected that, with this input, accidents and fatalities aboard our Naval vessels will be sharply reduced.

We don't want to point out only tragic errors. Human factors principles have been used to help make man's environment safer and more pleasant. Think about your automobile. Today it is rare to find a car which is not easy to steer and stop. However, if you've ever driven a 40's or early 50's model automobile, you can easily see how the human's strength limitations were taken into account when designing modern autos. Those old cars are nice, but they require more arm and leg muscle than some of us wished to use.

Because of the realization of the importance of Human Factors, we can also expect our military systems to be more effective as well as safer for our personnel to use. We can also expect to see human factors principles and concerns being used in private homes and industries. Adjustable chairs and kitchen counter tops which are built to accommodate 95 percent of the population are examples of household equipment which take human body measurements into account.

Human factors principles have also been used successfully in a wide range of situations. Restraining devices in automobiles have been designed using body dimensions calculated by human factors engineers. To continue in the automotive area, think about the road signs you see on every highway. The coloring, height-width ratio of the letters, as well as other aspects of the sign, all lead to an easy to read informational display. These factors of coloring, etc., were selected based on the results of traffic studies conducted by human factors people.

Other designed areas of your environment have used human factors principles to design safer, more efficient surroundings. For example, the effects of color in our environment have been investiaged to see if 'warmer' colors were considered to be more pleasant than 'cool' colors. They were. The catch is that this pleasantness doesn't necessarily lead to an increase in effective performance.

The quality of life has been improved because of attention to the human aspects of a situation. For example, certain surgical procedures have been made less dangerous because a design team redesigned instruments to

(Go on to the next page)

From Page 8

take advantage of the hand's bone structure. Now the surgeon can work with a minimum of hand strain instead of having to overcome the awkward position required when the original instrument was used.

Law enforcement systems have also taken Human Factors to heart. Information systems, protective devices and immobilizing devices have all used human factors principles to improve them. We could go on and on, but we don't want to belabor the point.

You've now seen examples of the tragic mistakes which can and do occur when human factors engineering (HFE) input is not considered, as well as examples of positive benefits we can derive in our everyday lives from using HFE knowledge. Perhaps it is time now to restate one of the basic questions which every human factors experts asks at the start of any design process. What do you think that question is?

(1) What errors have the initial design team made and how can they be rectified. Go to Page 59
(2) What are the requirements placed upon the human by the system in question, and what are his capabilities for meeting these requirements? Go to Page 48.
(3) What aspects of the design can be satisfied by training specifications? Go to Page 97.
(4) When will redesign be necessary? Go to Page 43.

From Page 19

(2) You indicated that the art of Human Factors Engineering is more important than the science. While it is important to 'think Human Factors,' you won't be very successful if you don't study the scientific applications. Return to Page 19.

From Page 13

(2) You indicated that keeping the student awake is the reason for questions. That's not really true. It might help, but it's not the real reason. Return to Page 13.

From Page 42

(3) Studying why people are unable to perform in a system is one of the purposes of Human Factors Engineering. If systems are designed properly from the start, you won't have to study why people cannot perform in a given system. Return to Page 42.

From Page 37

(2) So, you're taking this course only because you had to! We hope this isn't really so. If you feel that way now, we hope we can change your mind soon! (In fact, you won't be able to go on until you change your mind!) Return to Page 37.

From Page 18

(2) No? Ask your supervisor or your training coordinator for these documents before you go on. If you now have these documents, select the other answer and we'll proceed. Return to Page 18.

From Page 39

(1) Now, do you really want to choose this answer? Some of the areas already mentioned, such as selection of personnel, don't fit a purely machine system. Return to Page 39 and choose again.

From Page 32

(2) This answer is incorrect. These errors also were made, but they aren't adjustment errors. Return to Page 32.

From Page 34

(3) Very good, both of these approaches were used and helped to reduce the amount of pilot error and confusion.

Researchers discovered that information of certain types could be effectively presented to sensory channels other than the visual one. For example, 'radio range' was a system of interlocking auditory signals that allowed pilots to chart their approaches to the runway while flying 'blind.' Similarly, 'flybar' was introduced as a system of auditory signals which indicated the roll, bank, and turn of the aircraft. Controls were also coded through the use of different dimensions, sizes, and shapes to eliminate some of the errors which had occurred as a result of confusing one control with another. Thus, the senses of hearing and touch were used to reduce the visual load of the pilot.

The second approach involving the design of visual panels is epitomized by a study conducted in 1947 by Fitts and Jones from the Aero Medical Laboratory at Dayton, Ohio. They were tasked with surveying the psychological problems that related to the operation and use of aircraft equipment. Initially, they asked pilots if they, themselves, had ever made an error or had seen someone make an error in reading an instrument display or selecting a control. For example, one pilot gave the following account:

"I was flying at 25,000 feet in a P-47 on my first combat mission, but had mistakenly read the hands on my altimeter and was under the impression that I was at 35,000 feet. I called in some unidentified aircraft which were level with our formation, and consequently, actually were at 25,000 feet. Since I mistakenly reported them at 35,000 feet, they were assumed to be enemy aircraft. A good deal of confusion resulted. I believe some improvements can be made in our present altimeter."

Now, which type of error does this example illustrate?

(1) Errors in interpreting instruments. Go to Page 31.
(2) Reversal errors. Go to Page 45.
(3) Not reading the instruments. Go to Page 30.

From Page 1

What do you think is the primary reason for periodically questioning a student in self-paced instruction?

(1) To assure comprehension and provide immediate feedback to the student. Go to Page 15.
(2) To prevent the student from falling asleep. Go to Page 10.
(3) To provide the course with a grade. Go to Page 17.

From Page 19

(1) You indicated that the scientific aspect of Human Factors Engineering is more important than the art. While the science of Human Factors is indeed important, you can't overlook the importance of your attitude. Return to Page 19.

From Page 29

(1) We feel this is the correct answer. High speeds on our highways certainly are not a safety factor, nor is this much performance capability necessary for rapid starting from a standing position.

So, providing a statement of purpose is the first step in designing (and the first identifying characteristic of) a system. What do you think should be the next step in designing a system?

(1) Specifying the system's functions. Turn to Page 73.
(2) Selecting the personnel for the system. Turn to Page 3.
(3) Determining the cost of a system. Turn to Page 66.
(4) Building a prototype of the system. Turn to Page 37.

From Page 50

(1) The throttle equipment designs weren't necessarily inadequate. They functioned very well; however, they weren't standardized, and this led to fatalities, not an inadequate design. Return to Page 50.

From Page 80

(2) We wish this were true, but it isn't. Return to Page 80.

From Page 23

(3) Whoa! Let's not get carried away! We could make you an expert if we had that long. Return to Page 23.

From Page 13

(1) You indicated that feedback to the student and checking on comprehension are the main reasons for periodic questions. That's right. Before you go on to new topics we have to be sure you've understood what you've already covered. Since we can't see confused looks on your face, the questions are our only way of knowing that you are having trouble. Congratulations on following the paging directions.

In addition to the programmed data presented to you, you will use the student supplement which was issued to you before you began this lesson. As you go through each lesson, you will be asked to refer to this supplement. This supplement provides you with graphs, photos and charts; some practical work (math, drawings); and information which is 'nice-to-know.' Take a few moments before each lesson to look over the supplement material. (Page 21 of the supplement provides a course overview.)

Let us demonstrate how we will use the supplement. We have provided portions of an article written by Franklin V. Taylor on Page 4 of your supplement. The article gives you a good perspective on Human Factors Engineering. Take a few minutes to read the article and then tackle the following questions.

What is the main point which Taylor makes in this portion of his article?

(1) One of the human factors engineers' main concerns must be the availability of funds. Go to Page 32.
(2) Human Factors Engineering is concerned with personnel selection and training as well as the design of hardware. Go to Page 43.
(3) To design a system properly, the mechanical components and the characteristics of man and his role in the system must be considered. Go to Page 18.
(4) All of the answers presented here. Go to Page 3.

From Page 71

(1) Absolutely right. Smart was presenting so much information that Eager just could not attend to everything or process all of the information.

But, he and Smart had been good friends too long to let one night ruin their friendship, so I. M. thought he'd just forget it. In fact, he decided to give Smart a call and see if he'd like to go to the club. After all, it was only 10 o'clock (I. M. was a 'night person'). But a sleepy voice answered the phone, and I. M. soon found out that Smart was not a night person. The bridge game had 'done him in.'

Eager was in no mood to hit the sack now--he had set himself up for a big night. So he figured he'd catch up on his reading. But he forgot that day was a government holiday and the mailman didn't come. The latest edition of 'Scientific American' Magazine wouldn't come until the next day.

With nothing left to do, Eager got a snack from the refrigerator and thumbed through his bookshelf. As he passed 'Human Factors Engineering--An Introduction,' he remembered some things Smart had been telling him. He figured, 'What have I got to lose; I'll take a look and see if there's anything to it.'

The orientation booklet began with a brief history of Human Factors Engineering...

In ancient times, mankind was required to put in long hours of physical work in order to survive. The proof that man did work and has constantly worked lies in the fact that mankind still exists. Surmising that toil has never been a pleasant experience, we can conclude that man has spent a great deal of time over the years thinking about how he could get out of work, or how to make his work easier--the situation hasn't changed much today.

The ancient Greek culture had little regard for any kind of heavy work; it was actually seen as a curse. Plato and his followers saw work as the realm of slaves, not free men; the Roman Empire held similar ideas.

As we look at the derivation of the words in different languages for work, we get a clear understanding of mankind's feeling for the subject. The Italian 'lovovare' is taken from the Latin 'laborare'. What do you think it means:

(1) To suffer. Go to Page 54.
(2) To do physical work. Go to Page 95.
(3) To study, as in a laboratory. Go to Page 87.

From Page 13

(3) You think that grades are the reason for the questions. No, we are interested in your opinion of the course, but there is more to it than that. Return to Page 13.

From Page 48

(2) This isn't really sufficient. Go back to Page 48.

From Page 74

(2) Unlike the science fiction writers, we know that machines can only do what their design specifications call for, and therefore, they are extremely rigid. Return to Page 74.

From Page 47

(1) You indicated that you would check with a technical specialist available to you. That's correct. Therefore, one of your main objectives should be to become aware of who these people are and how you can contact them.

In addition to learning about Human Factors per se, you'll also become aware of how Human Factors Engineering fits into the military structure. You will study some ground rules and review some of the philosophy. As you'll see, there are many detailed specifications and standards which regulate the use of Human Factors in military systems. Who do you think needs to be most concerned with these regulations?

(1) Maintainers of systems/equipment. Go to Page 49.
(2) System designers. Go to Page 90.
(3) Operators of systems/equipment. Go to Page 59.
(4) All of these. Go to Page 38.

From Page 15

(3) Very good. This was Taylor's main point and you'll see it reiterated many times.

Another aid which will be vitally important to you, both for this course and your new job, is the package of military standards and specifications to which you should have access for reference purposes.

(1) Yes. Go to Page 41.
(2) No. Go to Page 11.

From Page 42

(2) You feel that Human Factors Engineering deals with keeping people in mind when systems are being designed. That's pretty good. The major aim of Human Factors Engineering is to maximize effectiveness through the enlightened use of humans. This can be done only if the human factors specialist concerns himself with the health, safety, comfort, acceptance, and performance of individuals.

Later in the course you will be given some detailed definitions and methods to use in systems design and evaluation; but for now, you've got the general idea. Human Factors Engineering involves designing with people in mind. Like many fields of study, there's both a science and an art to Human Factors Engineering. The science of Human Factors Engineering deals with principles and theories related to how men and machines, as well as men and environments, interact. The art of Human Factors Engineering is a more nebulous concept. By 'art' we're referring to your frame of mind. We want to get you to 'think Human Factors,' for when you allow the concepts of human engineering to pervade your thoughts, you will become a better practitioner.

For you to be an artist in the field of Human Factors Engineering you must, indeed, be intimately familiar with the scientific side. But a major concern of this course is to influence you on a deeper level than mere memorization of concepts.

Do you think the science or the art of Human Factors Engineering is more important?

(1) The science of Human Factors, since you must have knowledge of facts before you can develop a philosophy. Go to Page 13.
(2) The art of Human Factors is more important, because unless you develop the right attitude, factual data will be of no benefit. Go to Page 9.
(3) Neither is more important; they both must be considered. Go to Page 37.

From Page 73

(2) Correct. Receiving orders is a form of input.

In addition to identifying the broad categories of input, processing, and output for the system, each subsystem may also be identified in terms of its own input, processing, and output functions. In order to interrelate these various subsystems, it is necessary to establish the links which exist between components or subsystems in the system.

After defining the purpose of the system and specifying the input, processing, and output functions, the next step in the development of a system should be deciding which functions are to be performed by the machine and which are to be performed by the human. In making this decision, do you think that human factors concerns should be the only criteria used by the designer?

(1) No. Turn to Page 76.
(2) Yes. Turn to Page 92.

From Page 96

(1) Right on. Now, that was a common sense problem and you used some yourself in selecting the right answer.

Before the industrial revolution, man's capabilities far outweighed the technologies of the time. As we approached the era of industrial revolution, we saw what approximated an equity in man's performance capability and the state-of-the-art. But the demands of World War II led to a tremendous leap forward in technology, with an apparent neglect of the human beings's place in it. These rapid changes did not consider man's abilities and capabilities during the design and development processes. Instead, they relied on that marvelously adaptable machine, the human body, to accommodate itself to whatever came off the production line. One predictable outcome of this approach was that human errors were excessive in many military systems; technology per se is not at fault because it can't make errors. The key is to have man and technology become compatible.

Even after CPT Smart's explanation, I. M. was still not sure he understood just what Human Factors Engineering was all about. However, I. M. did understand that his partner had just saved his bid, so he asked Smart to explain a little more about Human Factors.

Smart explained that human factors engineers are interested in the design of equipment, making sure that it will function efficiently and, thereby, obtaining the organization's goals. To do this, not only must the equipment function effectively, but man must do so as well. In order to achieve this end, human factors engineers work closely with systems engineers. The human factors engineer applies relevant knowledge about the characteristics and behavior of man to the design of man-operated systems.

Now, which of the following do you think are of major concern to human factors engineers?

(1) Human concerns, such as safety, as well as human effectiveness. Turn to Page 39.
(2) Human effectiveness, but not human values such as safety. Turn to Page 78.
(3) Machine design instead of job design. Turn to Page 35.

From Page 73

(3) Touchdown at Phillips Airfield is an outcome function, not an input function. Return to Page 73 and try again.

From Page 80

(3) Now really! Shape up and select again on Page 80.

From Page 76

(1) You indicated by your answer that you feel trained individuals must be available before designing a new system. You are incorrect. If this were so, our technology would become stagnant. Go back to Page 76 and try again.

From Page 37

(1) You're right, what you really should try to get out of this course is the flavor of Human Factors Engineering. When we're done, you should think about Human Factors whenever you're doing your job.

By now we're sure that you're wondering how we intend to give you this 'flavor of Human Factors Engineering.' If you think about it, it'll be obvious that we'll have to go into some detail along the way (in other words, be 'scientific' as well as 'artful'). So, as you work through each of the 40 lessons, you will be given 'facts' as well as general descriptions. This material will be presented to you in such a way that it will be easy for you to see how it relates directly to the job you're doing. Let's face it, the government isn't going to spend a lot of money and time having you take this course unless they think they'll get something in return. So, this course is designed to help you do your job better.

We've divided this course into three general areas. The first section covers human capabilities and limitations. We'll look at how systems and equipment were designed in the past before any real awareness of Human Factors existed. In the second section we'll put man into the system--a weapons system, transportation system, it really doesn't matter. We'll examine how he fits--or should fit. Finally, we'll get to the 'nitty-gritty'--the application of Human Factors principles in the military.

Let's talk about how long it should take you to complete this course. First, the course is designed to be a 'self-paced' course of instruction. Because of this, the course has been designed to suit many different types of people. Each lesson should take you less than an hour to do. The average time will be somewhere between 35 and 45 minutes.

And what about the entire course--how long do you think it will take you to complete this course?

(1) One week. Go to Page 35.
(2) Two months. Go to Page 46.
(3) One year. Go to Page 14.

From Page 25

(1) Very good, you read Table 4-1 correctly.

Later in this lesson you will be introduced to the limits of man's processing abilities, but first, let's check in on LT I. M. Eager, CPT B. Smart, and the friendly 'get-together' at Smart's house.

After chitchatting for an hour or so with old friends and new acquaintances, Eager, Smart, and the others sat down for a friendly game of bridge. Before long, Eager and his partner began consistently under-bidding or over-bidding; this was in large part due to a discussion that had arisen between Eager and Smart centered around the importance of Human Factors Engineering. While Smart had been concerned with convincing Eager of the importance of HFE, he had begun to realize that Eager was attending more and more to the conversation and less and less to the game of bridge. As a result, Eager constantly forgot which cards had been played.

This brings us to a good spot to stop and reflect on some aspects of the bridge game and I. M. Eager's behavior. As was mentioned, Eager had begun to lose because he hadn't been able to pay attention to both the card game and the conversation. Why do you think this was so?

(1) Man cannot handle all the information with which he is bombarded. Go to Page 56.
(2) Although man can process all the information he receives, he sometimes has trouble separating the different sources of information in ways that can be clearly understood. Go to Page 51.
(3) The game had been going on for too long, and Eager had begun to think about calling out for some pizza and beer. Go to Page 75.

Cont'd

Lesson 4 is entitled

HUMAN FACTORS ENGINEERING

LESSON 4: BASIC INFORMATION PROCESSING, OR IS MAN A MACHINE?

Hello, again, and welcome to the fourth session of Human Factors Engineering. Thus far, you have been introduced to some general information about Human Factors, as well as some of its practical applications. In addition, you have been shown some of the effects of poor Human Factors Engineering. In this lesson you will begin to 'home' in on some important, specific factors that must be taken into account when dealing with the interaction of man and machine.

In order to deal with some of the information presented in this lesson, it will be necessary for you to read the section in the supplement for Lesson 4. This selection deals with some practical applications of research findings on basic information processing. More specifically, man's ability to process information will be compared to that of a machine. In the process, the capabilities and limitations of man as a processor of information will be discussed.

Cont'd on Pg. 71

Now, your supplemental readings presented Miller's findings on the number of bits of information that define our channel capacity. From this supplemental information, answer the following question: The number of bits of information (H) which can be effectively transmitted using only loudness as a stimulus dimension is:

(1) 2.3. Go to Page 24.
(2) 5. Go to Page 42.
(3) 7.2 Go to Page 59.
(4) 4. Go to Page 56.

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From Page 56

(2) Correct, man's auditory system is physiologically capable of handling sound waves that range from 20 to 20,000 cycles per second. Thus, signals below or above such limits are beyond the scope of human processing. (Other animals have capabilities that differ from those of humans. This might be of interest, for instance, when designing auditory signaling devices because of the way these devices might impact on the animal's behavior. More information of an auditory nature will be presented in a later lesson.)

As you can see, man is limited physiologically in terms of what types of auditory information he can handle. (Stop and think how man's other senses also limit his processing ability.) Along with these limitations, there are certain constraints on the amount of information man can handle. If you remember from reading the supplement prior to beginning this lesson, a discussion of Miller's article on channel capacity was presented. While the limit for man's ability to process information in absolute judgments was established at two to three 'bits' of information, man's actual processing ability is greater than this if judgments are based on more than one dimension (such as brightness and hue).

While keeping in mind that absolute judgments are rarely used in real world situations, the 'rule of thumb' to keep in mind when designing equipment is that the upper limits of man's channel capacity are limited to five to nine separate stimuli or pieces of information. This rule then, in effect, provides a safety check for human factors engineers, when making decisions that involve lower and upper limits of man's processing capability.

As a practical test of Miller's findings, answer the question posed by the following situation. Suppose that colors (hues) were used to code electrical wires on an instrument panel, and errors of identification could be very costly. What would you, as the head engineer on the project, recommend as the upper limit of the number of colors to be used in the wiring of this panel?

(1) Nine colors. Go to Page 83.
(2) Five colors. Go to Page 97.
(3) Seventeen colors. Go to Page 78.
(4) Three colors. Go to Page 51.

From Page 6

(1) Sorry, but we fooled you. Printed material is read from left to right, not the other way around. Return to Page 6.

From Page 30

(4) We wish it were so. Go back and choose a higher value from Page 30.

From Page 74

(3) Men aren't terribly reliable, especially when compared to the reliability of machines. Men also are not rigid, but flexible. Return to Page 74.

From Page 61

(1) You're getting smarter all the time. Once again you've answered the question correctly.

Efficient processing of information involves the learning of both stimulus and response codes, as well as the appropriate relationship between the two. For example, when trying to remember items you need to buy at the grocery story, it might be beneficial to group them according to food types, such as fruits, vegetables, meats. This categorizing or coding of information, then, increases one's ability to store and retrieve that information.

The systems approach to human engineering began to develop about the time advances were being made in the area of communications theory, including a new approach to information measurement. This new notion was that information could be defined in terms of the 'reduction of uncertainty,' with uncertainty described in terms of the number of alternate messages and their probabilities of occurrence.

This information measurement enables us to describe the amount of information transmitted by a system in terms of uncertainty or 'noise' in the system. Thus, the amount of information transmitted by the system reflects:

(1) The amount of information in the response. Go to Page 79.
(2) The amount of information in the stimulus only. Go to Page 61.
(3) The correspondence between input and output messages. Go to Page 53.

From Page 39

(2) Very good. If people interact with it, human factors expertise can help enhance that interaction, as well as make it more efficient.

Besides man-equipment systems, human factors engineers are concerned with man and his environment, and not just the atmospheric environment either. Environment can also relate to the physical space in which a person works and lives.

Personal items, such as hand tools, clothing, and safety gear (e.g. ear plugs) are also of concern to the human factors engineer.

Since the man-machine system is the area of greatest concern for this course, let's take a more detailed look at just what a system really is.

Most systems, of whatever nature, have certain characteristics in common. Those characteristics will be identified below by discussing the steps typically followed in the design and development of a system. First, any system may be defined in terms of the purpose of the system. This seems so obvious that we were almost ashamed to put it in the text. However, we bet you can think of some systems whose stated purpose is not consistent with the operation (or actual objective) of the system. For example, automobiles which can reach speeds of 120 mph have high performance as their stated purpose. However; we wonder if this is the true purpose. Which of the following do you think is the main reason that speeds of this magnitude were incorporated into automobile design features?

(1) As a selling point. Turn to Page 13.
(2) As a safety feature. Turn to Page 81.
(3) To provide quick starting capabilities. Turn to Page 38.

From Page 6

(2) Very good. Typically, we do use red as a signal to stop and green is used as a starting indicator.

Today there is a concerted effort to use human factors engineers not so much to correct faulty design, but more and more to be a part of the original design team. In this way, tragic errors can be prevented. However, this concept is just beginning to be fully used.

Given that we know the importance of Human Factors Engineering in reducing human error, and also given that these concepts haven't been fully used, which of the following do you think is the current proportion of system failures that are caused by humans in a weapons system?

(1) The current proportion is even worse than that found by Fitts and Jones --90 percent of the errors are human ones. Turn to Page 43.
(2) 50-70 percent of the errors are due to human failures. Turn to Page 80.
(3) 20 percent of the errors are human ones. Turn to Page 7.
(4) 10 percent of the errors are human ones. Turn to Page 27.

From Page 12

(3) The pilot did read the instruments, but he didn't read them correctly. Return to Page 12.

From Page 12

(1) Absolutely. This is the type of error which was made. In fact, the kind of error involving an instrument which has more than one pointer accounted for 48 out of 227 pilot-error experiences.

From these pilot experiences Fitts and Jones classified eight types of pilot error. We will present these briefly for your review:

(1) Errors in interpreting multi-revolution instruments. The consequence of this type of error was presented in your last question.

(2) Reversal errors such as interpreting the compass direction incorrectly occurred the second most frequently, accounting for 47 of the 227 pilot error experiences.

(3) Legibility errors due to difficulty in reading instruments accounted for 37 errors.

(4) Substitution errors were made when the pilot confused one instrument for another, or confused which machine (e.g. engine) was being activated by which control. This type of error occurred 36 times out of the 227 total errors.

(5) Using an inoperative instrument (25 of 227).

(6) Misinterpreting scale markers (15 of 227).

(7) Illusions (14 of 227).

(8) Failure to notice the occurrence of a signal, such as a warning light (5 of 227).

As you can see, common sense would suggest strategies for correcting most of these categories of errors. That is, the fact that a lot of pilots reported serious errors in reading multi-revolution indicators suggests that this type of display needed to be redesigned so as to prevent such confusion. An example of such a redesign is the digital readouts displaying many values in current military aircraft instead of the traditional clock face indicators. Altimeters now indicate tens of thousands of feet with an Arabic numeral in place of a third clock hand. The above survey dealt with errors which were made because of poor designs of instrument displays and signals. Another similar survey was conducted by Fitts and Jones dealing with the types of errors made by pilots in operating aircraft controls. In this study 460 errors were counted and these were categorized into six classes of errors.

(Go to the next page)

From Page 31

Substitution errors were due mostly to lack of uniformity of control design, inadequate separation of controls, and/or the lack of a coding system to help the pilot identify controls by the sense of touch alone. For example, in the early days of retractable landing gear, pilots often grabbed the wrong lever and mistakenly raised the landing gear instead of the flaps. Needless to say, if you have just landed an aircraft and then proceed to raise the landing gear by mistake, you are in for trouble.

Other types of errors found were adjustment and forgetting errors. What type of control errors do you think would be classified as adjustment errors?

(1) Operating a control too slowly, or turning a switch to the wrong position, or following the wrong sequence in operating several controls. Turn to Page 6.

(2) Difficulty in reaching a control, confusing one control for another and/or forgetting to activate a control. Turn to Page 11.

From Page 15

(1) Design-to-cost has become an accepted military concept, but Taylor did not address cost at all in this portion of his article. Return to Page 15.

From Page 90

(2) You indicated that getting the job done well is our prime objective. That's correct. After all is said and done, that's the name of the game.

So, by now you've got a clear idea as to what your objectives should be. You can see that completing this course will help you do your job better. If this doesn't become more obvious to you as you progress in your studies, then something is wrong. But we think you'll notice how this course helps you right from the start. If you're like most prospective students, your background in Human Factors Engineering is minimal. Therefore, the course is geared to suit you. We'll start from the basics and work our way up to some of the more complex issues. The information presented in this first lesson has been geared to give you an overview of the course and explain why this material is important for you. Don't be discouraged and think the course will be boring or that it will be so easy you could get through without any effort. As you progress, the information presented will become more technical and detailed and the questions more challenging. But on the other hand, don't worry that the information will go over your head. If you weren't capable of handling this type of course, you would not have gotten to the position you're in now. So get ready!

To make a somewhat dry topic more interesting, we've clothed our lessons in a story line. The protagonist of our story is someone who might be just like you (although many of you may want to deny this!). His name is Lieutenant I. M. Eager. LT Eager is an example of a student who, like many of you who take this course, came with mixed emotions (some bad, some worse). By the time he went bravely forward from this citadel of knowledge he had something new--a new love, a large bank account (his rich uncle died while he was taking the course) and a better understanding of Human Factors Engineering. We don't guarantee love or money, but if you stick with us, we'll do our best to have you leave with an appreciation and understanding of Human Factors.

So, are you ready to learn a little bit more about LT Eager and Human Factors Engineering? We hope so. Lesson 2 will explain some common HFE terms and explain to you why Human Factors is so important. So, when you're set, begin Lesson 2 which starts on Page 40.

From Page 50

(2) Correct. It is indeed a tragedy that so many people died because machines were designed without the proper emphasis on the human and without the application of human factors principles, thus causing human errors to occur.

One of the reasons for so many costly errors was the fact that the capabilities of the human were not clearly differentiated from those of the machine. Furthermore, human performance capabilities, skill limitation, and response tendencies were not adequately considered in the designs of the new systems that were being produced so rapidly. For example, pilots were often trained on one generation of aircraft, but by the time they got to the war zone, they were required to fly a newer model. Unfortunately, the newer model was usually more complex than the older one and, even more detrimental, the controls may have had opposing functions assigned to them. Some aircraft required that the control stick be pulled back toward the pilot in order to pull the nose up. In other aircraft the exact opposite was required; namely, in order to ascend you would push the stick away from you. Needless to say, in an emergency situation many pilots became confused and performed the incorrect maneuver, thereby causing disastrous results. Fortunately, the 1950's brought a strong program of standardizing control shapes and locations.

Sensory overload also became a severe problem, especially in cockpit design. Think about the last time you were in a cockpit or saw a picture of one. Responding to all those lights and switches can be a bewildering experience. Which of the following approaches do you think was taken in order to overcome some of the pilot's visual overload?

(1) Visual displays were designed to be more efficient. Turn to Page 45.
(2) Information was presented to other sensory channels such as hearing and touch. Turn to Page 91.
(3) Both approaches presented here were used. Turn to Page 12.

From Page 21

(3) Job design is an important aspect of Human Factors Engineering. Go back to Page 21 and try again.

From Page 6

(3) Nope. Not this time. Only one of these answers represents a typical way we respond. Return to Page 6.

From Page 23

(1) Well, you surely are industrious. However, this isn't the type of course to be taken in so short a period; you should give yourself a little more time. Return to Page 23.

From Page 76

(2) You are correct. While it would simplify the developmental process if there were people who were trained to perform a given task, this is not a prerequisite to system design.

Based on his task analysis, the human factors engineer must determine the extent to which the required behaviors can be achieved through the use of other available means (i.e., job aids, personnel selection, and training). To utilize these techniques, however, the system designer must know what man's performance capabilities are. For this reason, later lessons will discuss the physiology of man's sensory systems. Given this background understanding, the human factors engineer will be able to decide if the required behaviors can be achieved by providing job aids to facilitate human performance. Job aids are illustrated by checklists and operator manuals. Aptitude tests can also be developed to assist in the selection of individuals already capable of performing in the system environment. Finally, training, both at the individual and team level, is conducted to establish personal skills which enhance the performance of a total given system.

If it is determined that even with the use of these other means, man is not capable of performing a specific task, what should the designer do first?

(1) Terminate the entire development process. Turn to Page 52.
(2) Re-evaluate the assignment of functions to man and machine. Turn to Page 4.
(3) Revise mission requirements. Turn to Page 81.

From Page 19

(3) You're right! You must be aware of facts and principles, but it's just as important to 'color' your thinking with human factors concepts.

So the first question is: How can we get you to understand the principles and theories and also to think 'Human Factors?' Actually, the process is quite simple. If you can see the validity of the varied human factors concepts, this understanding and mindset will come quickly. This leads us to why you're sitting with this text taking this course. Before we tell you how and why we've designed this series of lessons, let us ask you your feelings. Why do you think you're taking this course?

(1) To become aware of the basic issues of Human Factors Engineering. Go to Page 23.
(2) Because the supervisor said it's required. Go to Page 10.
(3) To become expert in as many areas of Human Factors Engineering as possible. Go to Page 52.

From Page 13

(4) This is part of the system's acquisition cycle, but shouldn't come this soon. Return to Page 13 and try again.

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From Page 18

(4) All of these people are concerned with Human Factors, but only one is required to implement the regulations. Return to Page 18.

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From Page 90

(3) You indicate that providing a human factors vocabulary was our most important objective. You do need to 'know the words,' but there is more to it than that. Return to Page 90.

- -

From Page 29

(3) This may have been one of the stated purposes, but we don't think it was the true purpose. Try another answer from Page 29.

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From Page 21

(1) You're right, human factors engineers have as their highest priorities both the value and the effectiveness of human beings.

Since we are interested in both concerns, the human factors engineer is needed in such diverse activities as job design, job aids and training materials development, as well as the selection and training of personnel.

Typically, human factors engineers will approach a human factors problem from the point of view of the man-machine system. That is, they will give major consideration to the interaction of one or more persons with any physical component or piece of equipment within the system. However, consideration of just the man-machine interaction may be too narrow in approach. The human factors engineer knows that man also interacts with system components in addition to the equipment subsystems.

Can you pick which of these system components require the attention of a human factors engineer?

(1) Machine systems or subsystems are the sole concern of human factors experts. Turn to Page 11.
(2) Machine components, physical environment, any tool or item of equipment used by people in their daily lives. Turn to Page 29.
(3) None of these choices belongs in the realm of Human Factors Engineering. Turn to Page 49.
(4) Both machine subsystems and physical environments are areas of human factors concern, but personal equipment and work performance are not. Turn to Page 3.

Cont'd

HUMAN FACTORS ENGINEERING This lesson will try to help the trainee

LESSON 2: WHY HUMAN FACTORS

Lesson 2 will discuss

Hello, welcome to Lesson 2 ~~of your Human~~ Factors Engineering course. In this lesson you'll learn what Human Factors Engineering is all about. ~~We~~'ll try to ~~help you~~ understand its importance for man as he interacts with his job and his environment. In your student supplement you will find a diagram which will be discussed in this lesson. It might be a good idea for you to turn to Page 6 in the supplement before beginning this lesson. Don't rush, we'll wait.

As you can see, the thrust of this lesson will be the man-machine system. ~~As you may know already,~~ the man-machine system is composed of men, machines, training, tools, technical manuals, and the environment in which they interact. Each component in the system (the man, the machine or tools, the environment), in turn, can be considered a subsystem. You'll be reviewing how each of these 'subsystems' plays a role in the process of system development. Also in this lesson, you will be introduced to LT I. M. Eager and you'll see how he approached this course. I. M. was somewhat typical of the average student: young, bright and 'eager.' His college degree was in chemistry, but his major was in travel, sports, and people--not necessarily in that order.

Cont'd Pg. 50

Upon entering the service, I. M. Eager was ordered to a command where he had an enjoyable assignment. However, when this tour of duty was completed, I. M. received orders to report to a human engineering lab. He felt that this was the end, since he considered himself to be a scientist in the 'true sense of the word.' According to I. M., anything that dealt with such an inexact subject matter as human beings and psychology was inferior. To I. M., psychology really didn't fit into the category of reality. All we could get him to admit when we first met him was that if we had to classify psychology and Human Factors Engineering as scientific, then at least call them 'soft sciences.' After all, that psychology junk was just common sense, right?

Well, what do you think? What does Human Factors Engineering consist of?

(1) An exact or 'hard' science. Turn to Page 75.
(2) Purely common sense. Turn to Page 7.
(3) A combination of science and common sense. Turn to Page 96.

From Page 18

(1) Good. Let's take a quick look at them.

The first document issued to you is MIL-STD-1472, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities." Take a quick look at the Forword and Table of Contents. As you can see, there's a great deal of information in this document. You'll be using it quite a bit.

MIL-HDBK-759, "Human Engineering Design for Army Materiel" is another important reference source. Don't be overcome by its size. It is a reference document, and, as you progress through the course, you'll easily see its value.

MIL-STD-1474, "Noise Limits for Army Materiel" is much more limited in scope than either of the previous two documents, but if you thumb through its pages, you'll see that the data presented are specific and important to the design of equipment.

The U.S. Army's Human Engineering Laboratory at Aberdeen Proving Ground, Maryland, published Technical Memorandum 29-76 in September 1976 entitled "Guide for Obtaining and Analyzing Human Performance Data in a Material Development Project." This document will be an invaluable tool when you study the system development process and when you become involved in this process as a psychologist or an engineer.

The final two documents in your package contain some general philosophy and standard procedures for human factors engineering programs. These documents are Army Regulation AR 602-1, "Human Engineering Program" and MIL-H-46855B, "Human Engineering Requirements for Military Systems, Equipment and Facilities."

As you progress through each lesson, you'll be given assignments from these documents and from your supplement. But don't worry, the 'homework' will be brief. In fact, a 15 minute time limit has been set for those assignments. Sometimes, they will review what you've done in previous lessons. Most of the time they'll also serve as a lead-in to the next lesson. We think you'll find them both informative and interesting.

Now that we've given you a brief overview as to how the course will be presented, let's look at what it will be all about.

(Go to the next page)

From Page 41

It's obvious by the title that the course is about Human Factors Engineering (HFE). It may sound like an impressive title, but the subject is quite straight forward. What does the phrase 'Human Factors Engineering' mean to you?

(1) That field of engineering concerned with systems which have no automation. Go to Page 7.
(2) Those activities concerned with making things with people in mind. Go to Page 19.
(3) That branch of engineering which studies why people cannot perform in a given system. Go to Page 10.

From Page 25

(2) This figure is the number of levels which can be discriminated on an absolute basis, not the number of bits. Return to Page 25.

From Page 90

(4) You indicated that making the student aware of the role of Human Factors Engineering in the military was our most important objective. While that is certainly a necessary ingredient, it isn't the main reason for the course. Return to Page 90.

From Page 15

(2) Personnel selection and training are areas with which the human factors engineer is concerned, but Taylor did not address this topic. Return to Page 15.

From Page 30

(1) Things really have improved, but not very much. Return to Page 30.

From Page 9

(4) This question may come up due to rapid technological advances, but it won't be the basic question to ask in the initial design phase. Go back to Page 9.

From Page 74

(1) Very good. Men are flexible, and they may be inconsistent. We as human factors engineers should not overburden this flexibility, however, or we will have the possibility of overloading the system.

So, men are flexible, but not highly reliable, while machines are highly consistent and not flexible. We should use these capability differences when we design equipment. In so doing we should be able to save both lives and money by reducing potentially tragic or dangerous situations.

Well, this lesson has been an important one. Because it is of such a serious nature, we have minimized our attempts at humor. However, now that the lesson is over, let's look in on our hero, LT Eager. If you recall, Eager wasn't really eager about his new assignment, and Smart was smart to make a convert by telling Eager all about the tragic errors which occur when human factors principles are ignored. This was a good ploy and was having the desired effect. As Eager was becoming more eager, he was also being distracted from the game and soon began to forget to count trumps. This resulted in a more enthusiastic novice human factors engineer who went down doubled and redoubled. If you are interested in the results of his bridge game and in continuing your Human Factors course, tune in next lesson for... Basic Information Processing, or... 'Is Man a Machine?' Oh, by the way, there is a reading assignment for Lesson 4. It is in your supplement on Page 9. See you. Turn to Page 25 to start Lesson 4.

From Page 90

(1) You indicated that providing an awareness of reference data was your key objective. While this is important, it is only a means to an end. Return to Page 90.

From Page 34

(1) This approach was used and will be discussed later, but it wasn't the only one. Return to Page 34.

From Page 12

(2) While this was the second most common error found by Fitts and Jones, it is not the one presented. Return to Page 12.

From Page 23

(2) That's about what we figured, too. In general, it would be a good idea to try to complete one lesson per day.

So, if you set aside about an hour a day for a couple of months, you should have ample time to begin thinking in terms of Human Factors Engineering and understanding the role it plays in your job. Sometimes you'll be advised to try a group of lessons as a study segment. On other occasions a lesson may require some extra time; but, overall, five hours per week should do it.

You might be thinking, "Well, if this is 'self-paced,' why are they telling me to restrict my completion time?" Okay, that's a reasonable question, and we'll try to answer it.

Let's recall the main reason for the course. We said that it was to make you aware of the basic issues of Human Factors so that you could function better in your job. The key words here are 'your job.' Above all, we're concerned that you do your job well. If we were to expect you to complete this course in a week, well, you probably wouldn't even be doing your job. But, on the other hand, if we were to say, 'take your time, you've got a year,' then too much time would go by and your recollection wouldn't permit you to retain what we feel you need to receive as an integral package. So, in summary, this program is called 'self-paced' because there is no set schedule, only general guidelines for completing the course.

We think that by now we've given you a good overview as to how this course will be conducted, as well as some insights into the overall course objective. Before we end this first lesson, let's go into a little more detail on some specific objectives.

We've said a few times already that we want to give you the 'flavor' of Human Factors Engineering. To accomplish this, we have a series of terminal objectives which must be met; we've listed these, together with a very general course outline, in your student supplement. Before we get into the actual course, we'd like to review these terminal objectives with you so you can see exactly where we're going. First of all, get your supplement and turn to Page 2. The terminal objectives are listed there. At this time just briefly look them over since we will be discussing them. Before you begin Lesson 2 take a few minutes to review these objectives. For now, an overview will be sufficient. If you want to make any notes, go ahead. You'll be keeping this supplement when you have completed the course.

(Go on to the next page)

From Page 46

When working in any field of endeavor, it is important to be able to 'speak the language.' Therefore, one of the primary objectives of this course will be to familiarize you with some of the more important common terms of Human Factors Engineering. In addition, throughout the course we will cite reference material which presents more detailed information than can be found in the lesson. By reviewing the referenced material, you'll become familiar with what's available for research, and you will know where to look when you have questions. But what happens if you come upon something which isn't addressed in one of these documents?

(1) Check with one of the technical specialists available to you. Go to Page 18.
(2) Use your 'common sense.' Go to Page 81.
(3) Give up. Go to Page 100.

From Page 9

(2) Correct. This, indeed, is one of the most basic of human factors questions. If we took into consideration the answers to this question before placing the system into operation, perhaps we would have fewer tragic accidents.

There are three general types of man-machine incompatibilities. The first is task/group interference. This occurs when an individual who is properly performing his assigned task interferes with one or more other individuals who are attempting to perform their own tasks. Later in this course you will be given several lessons on task analysis. Proper use of this technique will help to alleviate such task/group incompatibility.

The second type of man-machine incompatibility occurs when two or more equipment subsystems cannot be used together, even if each separately meets the relevant human engineering criteria. An example of this type of incompatibility would be requiring a certain type of protective helmet to be worn by a gunnery crew member. But, by so doing, you make it impossible for him to use properly his optical sight because of the thickness of the helmet. This type of error or incompatibility could be reduced by the use of systems analyses prior to developing the equipment.

A third general type of man-machine incompatibility is the classic example of improper hardware design and its effect upon the operator. This is the type of incompatibility toward which this lesson as been addressed.

Now, which of the following do you think would be helpful in reducing this third type of man-machine incompatibility?

(1) Use our knowledge of man's capabilities and limitations in the design of hardware. Go to Page 69.
(2) Use our knowledge of the machine's capabilities and limitations in designing hardware. Go to Page 17.
(3) Both of these should be done. Go to Page 74.

- -

From Page 18

(1) Maintainers are impacted by human factors regulations, but they are not required to implement these regulations. Return to Page 18.

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From Page 39

(3) Maybe you need to start this lesson again. Go back to Page 39.

- -

From Page 50

(3) This is not what caused so many of the air fatalities. Return to Page 50.

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Cont'd. Lesson 3 (this lesson

The training)

LESSON 3 TRAGIC MISTAKES AND POSITIVE CONSEQUENCES

Hi, welcome back to your course on Human Factors Engineering. At our last meeting you were introduced to our hero, I. M. Eager, who didn't seem to be too eager about his new assignment to a human engineering lab. When we left LT Eager, he was attempting to enjoy an evening of bridge at his buddy's house. This friend, B. Smart, was engaged in two separate operations, winning the game and selling Eager on the importance of Human Factors in the design of military systems. Smart eventually realized that the two goals were not separate and distinct, but could be combined effectively. In order to impress upon Eager the importance of Human Factors Engineering, Smart began to relate instances of tragic mistakes which had occurred when designers had failed to adhere to human engineering principles. To balance his argument, Smart also told Eager about some positive outcomes which had occurred when designers had taken human factors principles into account. In doing this, Smart was able to distract Eager from the card game long enough to finesse several tricks...

Now, we don't think you are like LT Eager. You probably don't need to be convinced of the importance of Human Factors Engineering, especially after having already completed Lesson 2 of this course. However, we do want you to think about design problems that you have encountered in the past so that you may be able to prevent any tragic mistakes from occurring in the future. To help you do this we will present some true examples of poor Human Factors Engineering which led to costly mistakes in terms of both men, time, and money. Also, ~~we~~ will show ~~you~~ some improvements in equipment which have helped people to be safer, more comfortable, or operate more efficiently in their environments. Okay, let's begin.

Cont'd on pg. 25

During World War II, technology advanced at such a rapid rate that some machines were designed without applying human factors principles. As a result, these machines could not be effectively used by the human operator. During this time, it is estimated that over 80 percent of all aircraft fatalities were the result of one of the following factors. Which do you think is the responsible factor?

(1) Inadequate throttle design. Turn to Page 14.
(2) Human error. Turn to Page 34.
(3) Enemy engagements. Turn to Page 49.

From Page 24

(2) Your answer is incorrect. Man cannot handle unlimited amounts of information. Return to Page 24.

From Page 68

(1) Chapanis was making that point, but that's not all. Go back to Page 68.

From Page 26

(4) Three bits of information are transmitted when the upper limit of the number of colors is used. Not three colors. Sorry. Go back to Page 26.

From Page 37

(3) This course may be a step on the way to becoming an expert in Human Factors Engineering, but don't worry, we're not expecting you to be anywhere near an expert when you finish. However, we do expect you to become somewhat familiar with some of the more important human factors principles and how they may be applied in your work. Return to Page 37.

From Page 73

(1) The functions related to flying the craft should be considered as processing functions. Return to Page 73 and try again.

From Page 36

(1) Your desire to terminate at this early stage is discouraging. Several other options are still open. Return to Page 36.

From Page 28

(3) Correct, both input and output play a role in information transmission measurement.

A communication system has both input and output messages, and both the input and output messages are important in information transmission. Thus, the extent to which the input messages can be 'recovered' from the output data reflect the amount of information transmitted.

This brings you to the final aspect of the 'man system,' that is, the operator's response mechanism or output system. Can you think of any behaviors you'd classify as response or output behaviors? Which of the following choices would you think should be classified as part of the human's response system:

(1) The eyes and ears. Go to Page 58.
(2) The nervous system. Go to Page 79.
(3) The various muscle systems. Go to Page 77.

From Page 61

(2) The answer is incorrect. Encoding and understanding are the same as classifying and interpreting. Go back to Page 61.

From Page 16

(1) That's right. Apparently the Italians were true descendants of the Roman Empire, where work was dispised.

The Italians weren't the only people who felt that way. The French world 'travailler' is derived from a word meaning torture; the German word 'arbeit' from a word meaning pain. So, when your spouse asks you to do some work and you answer that it's a 'pain in the neck!', you're being very accurate!

In the early days, man's attempt to ease his work burden was quite slow and haphazard. Anthropologists have recorded that literally thousands of years passed before man learned that rocks and sticks could extend and enhance the use of his fists and arms. Several thousand more years passed before man developed the spear, the lever, and the wheel. Somewhere along the line, man learned to domesticate animals to help in more strenuous tasks.

While getting another snack, I. M. thought about all this and decided that it was fairly interesting, but wondered what the point was. What do you think?

(1) Man has given thought to making work easier from the day he realized he couldn't escape it. Go to Page 84.
(2) To understand any subject, you must examine its linguistic history. Go to Page 77.
(3) The study of work has high esteem in European technology, but the American society is lagging behind. Go to Page 87.

From Page 70

(1) This answer is pretty close, but it ignores some basic human requirements. Go back and try Page 70 again.

From Page 94

(4) Very good. It was a combination of national mood, the state-of-the-art of Human Factors Engineering and increased awareness which caused this shift.

The fourth and final era which Chapanis describes is the 'Cosmopolitan Era.' Till now, Chapanis reports, human factors research and findings pertain only to the American and western European cultures; the percentage of the world's population covered was relatively small. Until now, little application has been made in the less-developed countries of the world or the non-English speaking populations. Thus, Human Factors Engineering as a science is incomplete. As its horizons expand beyond the present geographic limits, Human Factors Engineering will become a more complete science...

It was almost 3:00 a.m. by the time I. M. finished reading the pamphlet. He now felt he knew a little more about Human Factors Engineering and was ready for Smart. But he was more ready for something else--to hit the sack.

Let's quickly review what you've examined thus far. First, let's look at a very basic concept. The subject you've studied has been referred to as Human Factors Engineering. Often you will see the terms 'ergonomics' and 'Human Engineering' used instead. What do you think the term 'ergonomics' means?

(1) A branch of physics concerned with the measurement of work. Go to Page 99.
(2) The study of work with an emphasis on the biological aspects of man. Go to Page 70.
(3) The study of work with an emphasis on economics. Go to Page 82.

From Page 24

(1) Good show, just the answer we were looking for. Man's ability to attend to different sources of information is limited.

Man cannot handle all the information he receives because he is not physically capable of doing so. In addition, from an efficiency point of view, it would not make sense for us to do so. If too much information was constantly being processed, man would have trouble making sense of what was there, as well as deciding on particular courses of action. Take a cocktail party for example. At any one time numerous conversations are going on all around you. If you try to comprehend everything that everyone is saying, you will end up understanding nothing that is said. Instead, you choose to pay attention to one conversation, listening to what is being said there, while basically ignoring all the other chatter that is going on around you. So you see, by selecting information that is of interest or importance to you, you are able to increase the likelihood of responding correctly to stimuli of importance, while limiting the chances of overloading your processing system and causing confusion or misinterpretation. Thus, through a process of selective attention, man chooses to deal with certain stimuli and to leave certain other sources of information unprocessed.

Besides being restricted by selective attention, an individual is further restricted in terms of his physiological capacities for receiving information. For instance, can you think of a physiological limitation on your auditory sense? Which of the following statements describes one of our auditory limitations?

(1) People cannot talk and listen at the same time. Go to Page 86.
(2) People are for the most part deaf to vibrations of the air below 20 or above 20,000 cycles per second and, for all practical purposes, they are restricted to half that range. Go to Page 26.
(3) People cannot hear any sound frequency if the loudness level is less than 60 decibels. Go to Page 73.

From Page 25

(4) Actually, 4 is the number of levels which can be distinguished when a combination of 6 auditory variables are used. Go back to Page 25.

From Page 83

(2) Well done. You indicated that providing the pilot with various standards by which to compare his actual experience would be a good way to increase efficiency. This is true. In fact, by doing this you would be converting his judgments from absolute to comparative or relative judgments.

So you can see, there are limitations on man's information processing abilities that must be taken into account when dealing with the design of equipment and the interaction of man with this equipment. Thus far you have seen how certain processing limits affect the type as well as the amount of information man is able to handle effectively. In addition, man actively filters out some information by the process of selective attention so as to limit the amount of information impinging on him to a manageable level.

Before you proceed with this discussion of information processing, let's check in on our hero, LT I. M. Eager, and see how he has fared, given the information we have gained about problems resulting from overloading man's processing capacities. Once again we find Eager in the process of 'losing big.' The game had begun to wind down, in large part due to the lack of patience of Eager's partner. The conversation between our two principal players had gone on for over four hours now, with CPT Smart presenting examples and discussing various concepts important to HFE. While Eager had had to agree with a number of points brought up by Smart and even had to admit that some of the equipment design problems were, in fact, probably due to a lack of input from the human factors arena, he still believed 'soft science' needed little formal training. According to I. M., the bulk of information applied to design specifications is common sense knowledge that anyone with just average intelligence can figure out on his own.

At this point, however, Smart brought up Eager's losing streak, and began to show Eager just how he had used his knowledge about man's information processing capability to capture hand after hand. Eager was not pleased by such an explanation, especially since he was the one who had been 'taken to the cleaners,' and became upset that his old buddy would use such a devious tactic to win. He was forced to admit, just the same, that it was, indeed, an effective strategy.

(Go on to the next page)

From Page 57

OK, let's review with Eager just what caused his downfall. At various points in this lesson, you have reviewed terms, such as selective attention, physiological processing limitations, channel capacity, absolute judgments, and relative judgments. In terms of the strategy or strategies employed by CPT Smart, which of the following do you believe contributed to Eager's predicament?

(1) Channel capacity. Go to Page 66.
(2) Selective attention. Go to Page 92.
(3) Physiological processing limitations. Go to Page 86.
(4) All of these things contributed to Eager's downfall. Go to Page 60.

From Page 53

(1) Oh, come on, you should know better than that. After all, we've discussed the importance of these sense organs as input mechanisms. Go back to Page 53.

- -

From Page 18

(3) Operators are, of course, concerned with human factors regulations, but they are not required to implement these regulations. Return to Page 18.

- -

From Page 9

(1) You may eventually need to ask this question, but it shouldn't be necessary to do so at the start of a design process. Go back to Page 9.

- -

From Page 25

(3) Actually, 7.2 is the number of bits of information transmitted when a combination of 6 auditory variables are used. Return to Page 25.

- -

From Page 58

(4) Very good. See, you have learned something from this lesson so far.

Man as a processor of information is affected by various internal and external factors. Physiologically, man is limited in terms of what and how much he can process at any one time. In addition, he limits the amount of information impinging on him from the environment by selectively attending to certain stimuli, while blocking out or reducing the amount of input from other stimuli. Thus, when man attempts to attend to too many sources of information at once, effective responding to any one source is greatly limited.

Now that you've examined specific capabilities and limitations of humans, let's re-evaluate the human system, and the processes involved in incorporating the human system into the man-machine system. This general view was briefly discussed in Lesson 2. It might be advisable to glance back at the diagram (Figure 2.1) presented in that lesson in your supplement.

At the point of a man-machine interaction, the human operator receives information through his senses. As has been discussed previously, this is the first aspect of Taylor's model (Figure 2.1 where human limitations must be taken into account). Sensory psychology has had much success in specifying these limitations. However, this research has frequently been limited to the laboratory instead of more realistic performance situations. Thus, for example, the thresholds above which people can begin to detect visual or auditory stimuli has been determined in a number of laboratory experiments. Beyond these highly controlled laboratory environments, human factors engineers are concerned with such things as an operator's ability to hear a warning bell in the presence of noisy background, or detect a signal while scanning an instrument panel.

(Go on to the next page)

From Page 60

Once information is sensed by the machine operator, he does not simply act as a relayer of information. Instead, sensed information must be classified and interpreted in some way. This is done by comparing the sensed information with other information previously stored in memory. Even though the information is properly classified and clearly understood, there is no guarantee that the operator will make a correct response. Why do you think this is so?

(1) Just because information has been placed in memory doesn't mean it can be retrieved for processing or for use in selecting an appropriate response. Go to Page 28.
(2) Even though the information has been encoded and understood, this doesn't mean it has been classified and interpreted. Go to Page 53.
(3) Both of these answers are correct. Go to Page 87.
(4) Neither of these answers is correct. Go to Page 100.

From Page 28

(2) The answer is incorrect. There is more involved than just stimulus input. Return to Page 28.

From Page 77

(1) This answer is not correct. The process is indeed ordered correctly, but your logic is faulty in that the system encompassing the five step process is the man-machine system, not the human system. Return to Page 77.

From Page 71

(2) Not really. No physiological limits were exceeded. Go back to Page 71.

From Page 68

(2) Chapanis was making that point, but that's not all. Go back to Page 68.

From Page 85

(4) You indicated that better equipment design as well as better selection and training of personnel would have prevented many of the problems encountered during World War II You're correct.

This was the hard lesson we learned from World War II. Early in the design stage of system development both personnel and equipment must be taken into account; designing a weapons system that is technically correct in terms of its equipment is only half of the story. The time lag between the start of what has come to be called engineering phychology research and the design, manufacture, and deployment of new or redesigned weapons systems is often as long as five years. During the war the emphasis changed to research on selection and training, and, by the end of the war, some success was attained.

It was with this research that the field known today as Human Factors Engineering was born. Although begun during World War II, the level of research in the U.S. was low until after the war ended in the mid-forties.

The growth of Human Factors Engineering during the mid- to late-forties was evidenced by the establishment of several organizations to conduct psychological research on equipment design. Toward the end of 1945, Paul Fitts established what came to be known as the Behavioral Sciences Laboratory at the Army Air Corps Aeromedical Laboratory in Dayton, Ohio. Around the same time, the U.S. Navy established the Naval Research Laboratory at Anacostia, Maryland (headed by Frank V. Taylor), and the Navy Special Devices Center at Port Washington, New York (headed by Leonard C. Mead). The Navy Electronics Laboratory in San Diego, California, was established about a year later with Arnold M. Small as head.

In addition to the establishment of these military organizations, the development of a human factors discipline is evidenced by the growth of several civilian activities. Contract support was provided by the Navy and Air Force for research at several noted universities, specifically Johns Hopkins, Tufts, Harvard, Maryland, Holyoke, and California (Berkeley). Paralleling this growth was the establishment, by Jack Dunlap, of the Biomechanics Division in the Psychological Corporation. This later became a separate corporation—Dunlap and Associates. Thus, we can see that as a direct result of the efforts of World War II, a new industry known as engineering psychology or Human Factors Engineering was born.

(Go on to the next page)

From Page 63

In the decade following World War II, engineering psychology continued to grow. In 1951, the Army entered the field with the establishment of what is now the Human Engineering Laboratory at Aberdeen, Maryland. This lab has grown into an organization of about 200 people...

It was almost 2:00 a.m. and Eager had had a hard day. But the background of Human Factors Engineering had given him a new look at his upcoming job. He was beginning to think that maybe there was something to it. Anyway, he figured he'd finish this pamphlet before he hit the sack, so he'd have a little ammunition if Smart attacked him again the next morning.

The next section of Eager's pamphlet on Human Factors Engineering dealt with the development of the field. Before we examine what some noted human factors engineers have said about this development, please answer the following question for us. From our review thus far, where would you say man's use of human factors information actually began?

(1) During the industrial revolution. Go to Page 72.
(2) During World War II. Go to Page 95.
(3) With the organization of the Army Air Force Aeromedical Lab. Go to Page 91.
(4) None of these. Go to Page 67.

From Page 70

(3) Of course. In fact, Army Regulation (AR) 602-1 defines it just that way.

In summary, Human Factors Engineering has come a long way. It started out with man's attempts to make his work easier and has reached the point where it is an integral part of nearly every major design program. The U.S. Army has implemented Army Regulation (AR) 602-1 which 'prescribes policies and procedures and assigns responsibilities for Human Factors Engineering in the Department of the Army,' The Navy has dedicated resources to ensure that Human Factors Engineering is incorporated in all naval systems. Organizations such as the U.S. Navy Pacific Missile Test Center at Point Mugu, California, and the Manning Controls/Integration Branch of the Naval Sea Systems Command are two examples. In every large industry you will find industrial engineers and human factors engineers working to implement the many ideas generated throughout the long history we have just reviewed. The field has by no means reached the point of stagnation. New ideas are generated constantly. That's what makes Human Factors Engineering so exciting. As you continue with this course, we think you will see that the excitement is contagious.

You've now completed the introductory section of this course. You've been primarily concerned with the past in these lessons. Why do you think we've emphasized history thus far?

(1) To show the student that history is made by individuals just like him. Go to page 82.
(2) To indicate what can happen when HFE is ignored. Go to Page 99.
(3) To allow the student to see the overall picture of HFE. Go to Page 70.
(4) All of these answers are correct. Go to Page 98.

From Page 13

(3) Determining the cost may be a part of your job, but this can't be done at this stage of system development. Go back to Page 13 and try again.

From Page 58

(1) Correct, channel capacity does influence a person's processing ability, but other variables affect man's ability as well. Return to Page 58.

From Page 64

(4) You indicated that none of the listed events or time frames marked the beginning of man's use of human factors information. You are correct.

As we discussed earlier, man's use of human factors information has really existed since man first began to think about his work. The discipline did not become formalized until much later, but, nevertheless, many of its concepts were in use.

An excellent outline of the stages in the development of Human Factors Engineering is presented by Dr. Alphonse Chapanis of Johns Hopkins University in the book 'Ethnic Variables in Human Factors Engineering.' Chapanis prefaces his outline by stating that while clear lines cannot be drawn between the stages of development of any discipline, there are obvious differences in eras. He lists four stages in the development of Human Factors Engineering. They are:

(1) Pre-technology
(2) Aerospace
(3) Socio-technical
(4) Cosmopolitan

A description of each era follows.

The first era, described by Chapanis as the 'pre-World War II' stage or the 'pre-technology era,' encompasses a period beginning in ancient times when man first developed tools for his own use and ending at the beginning of World War II. While this stage is generally informal, the use of human factors concepts during this time is, nonetheless, evident. This period encompasses all events from the development of the wheel to the time-and-motion studies of the Gilbreths. Other major developments of this era were the organization of the Industrial Health Research Board, The National Institute of Industrial Psychology (both in England), and the Psychological Corporation in the United States.

(Go on to the next page)

From Page 67

The second era in Human Factors Engineering Chapanis calls 'the World War II and aerospace era.' The details of World War II and its effects on Human Factors Engineering were explained earlier. Chapanis summarizes this era by stating that the systems developed for use during the war 'placed demands on the human that often went beyond the capabilities of human senses, the brain, and muscles... These demands raised problems about human performance, capabilities, and limitations that could no longer be answered by common sense and the work study engineers' principles of motion economy.'

Which of the following points do you think Chapanis was trying to make with this statement?

(1) We had entered a 'man versus machine' stage wherein hardware technology had surpassed human engineering technology. Go to Page 51.
(2) Only systematic research could solve the problems of this era. Go to Page 62.
(3) From now on, much more emphasis would need to be placed on performance capabilities and requirements. Go to Page 71.
(4) All of these. Go to Page 93.

From Page 48

(1) This isn't really sufficient. Return to Page 48.

From Page 83

(1) This wouldn't be such a good idea; by relying on trial-and-error, your fatality rate might be quite high. Return to Page 83.

From Page 71

(4) Look a little more closely. There is a general term for what Smart was doing. Return to Page 71.

From Page 65

(3) We hope you've been presented an overview of HFE, but our objectives were broader than that. Go back to Page 65.

From Page 55

(2) This is a tough one, but you've hit the nail on the head.

Ergonomics is really the title given to Human Factors Engineering on an international level. The emphasis of European scientists sometimes leans toward the physiological, but the overall perspective is the same--improving the efficiency of man and machine in a given system.

Now a question which is a little easier: What do you think the term 'Human Factors Engineering' means?

(1) A comprehensive effort to integrate personnel skills, training, behavorial reactions, human performance data, and biomedical factors into doctrine to assure operational effectiveness. Go to Page 54.
(2) A biological sub-discipline devoted to altering the human make-up to better fit technology. Go to Page 82.
(3) A comprehensive technical effort to integrate all personnel characteristics into doctrine and systems to assure operational effectiveness, safety, and freedom from health hazards. Go to Page 65.

Cont'd

HUMAN FACTORS ENGINEERING

Will discuss

LESSON 5 HISTORY AND RELATED TECHNOLOGY, OR HUMAN FACTORS, THIS IS YOUR LIFE

So far we've introduced you to the course, talked about some general human factors topics, given you some examples, and followed the heroics of LT I. M. Eager as he moved along to his new duty station. ~~In~~ Lesson 5 ~~we'll see~~ how the science of Human Factors evolved as well as examine some related sciences.

First, let's see what's happening to Eager. When we last left him he was suffering from a combination of beer, pizza, and a long game of bridge. As he awoke from his nap, the thing that bugged him most was the way his 'buddy,' CPT B. Smart, had taken advantage of him. As you recall, Smart finessed Eager in more ways than one. Smart's 'modus operandi' had been threefold: 1) he distracted Eager with the loud stereo; 2) got him a little high on beer so he couldn't think straight; and 3) argued about Human Factors so I. M. wouldn't pay attention to the game. In human factors terms, how would you describe what Smart was doing?

(1) He was overloading Eager's attentive and processing capacities. Go to Page 16.
(2) He was exceeding Eager's physiological capabilities. Go to Page 62.
(3) He was negating Eager's capacity for selective attention. Go to Page 100.
(4) All of the answers presented here. Go to Page 69.

From Page 68

(3) Chapanis was making that point, but that's not all. Go back to Page 68.

From Page 64

(1) You indicated that you felt man's use of human factors information began during the industrial revolution. Well, it's true that the role of Human Factors became more obvious as the world became industrialized, but man's use of human factors information existed long before the 19th Century. Go back to Page 64.

From Page 94

(3) Realization that the problems of man-machine interaction extended beyond military matters was an important factor, but other variables also contributed to the shift. Go back to Page 94.

From Page 13

(1) Well done, this was a pretty difficult question and you chose correctly.

All the answers to the previous question are important in the development of a system. But the second step in developing a system (and the second major characteristic of a system) is a definition of the functions that the system is to perform. Let's use an example. Suppose you want to design a system that could move from one place to another very rapidly, and you wanted the system to be able to do this when the start and stop places had limited access. In essence, you want a jet helicopter of some type. Before building such a machine you should specify its functions. Now, functions can be assigned to any one of three categories: input functions, processing functions, and output functions (and systems may be further characterized in terms of their inputs, outputs, and procedures for processing inputs). With respect to the jet chopper, which of the following answers is an example of an input function?

(1) The process of flying the chopper from area one to area two. Go to Page 52.
(2) A radio directive from the command center. Go to Page 20.
(3) A touchdown at Phillips Airfield. Go to Page 22.

From Page 56

(3) You are incorrect. We can hear sounds at a much lower level than 60 decibels. Go back to Page 56.

From Page 48

(3) Correct. We want to use our knowledge of both man and machine capabilities when designing hardware. In this way we may be able to reduce these tragic mistakes you've been hearing about.

In the last few pages of this lesson we will give you some generalizations about the relative capabilities of both man and machine. Future lessons will deal with specific sensory and motor performance capabilities of the human operator.

Generally speaking, men are better than machines in their ability to perform the following types of tasks:

(1) Sensing very low levels of sensory stimuli.
(2) Recognizing patterns of complex stimuli which may vary from situation to situation.
(3) Sensing unusual and unexpected events in the environment.
(4) Retrieving pertinent information from memory.
(5) Using past experience in making decisions.
(6) Acting in an emergency.
(7) Selecting alternative modes of operation if needed.
(8) Developing new solutions to problems.

Machines, on the other hand, are generally better in performing these types of tasks:

(1) Monitoring for prespecified events.
(2) Storing coded information quickly and in large volume.
(3) Performing repetitive activities reliably.
(4) Exerting considerable physical force in a highly controlled manner.
(5) Maintaining performance over long periods of time without exhibiting any decrements due to fatigue.
(6) Maintaining efficient operations even under heavy load or under distractions.

Well, based upon these general capabilities, which of the following statements is most correct?

(1) Man is flexible, but may be inconsistent. Go to Page 44.
(2) Machines are flexible, but may be inconsistent. Go to Page 17.
(3) Man is highly reliable, but rigid. Go to Page 27.

From Page 40

(1) You indicated that Human Factors Engineering is an exact or 'hard' science. We wish it were so. We as human factors engineers have not achieved the precision that physicists, biologists, and other 'hard' scientists have. Return to Page 40 and choose again.

From Page 24

(3) While it's true that Eager's attention might have been diverted by such thoughts, there were other factors involved as well. Go back to Page 24.

From Page 83

(3) This answer might be feasible if pilots would always fly in squadrons. However, we're afraid the pilot would be in hot water if he were required to fly alone. In fact, even with a number of pilots, you'd still have to rely on all the other pilots' absolute judgments. Return to Page 83.

From Page 20

(1) You are correct. Human factors concerns are only one variable affecting the overall design of a man-machine system.

Other factors which must be considered include performance requirements, cost, reliability, safety, maintainability, and producibility. None of these can be viewed independent of the others. Human Factors interact with all of them as they interact among themselves. Trade-offs must be anticipated in order to realize an overall system which best suits all requirements.

Once the decision has been made concerning what functions the human and machine components will perform, the designer of the human conponents must describe in detail those tasks required of the man. The tasks must be analyzed (by conducting a task analysis) and then packaged into jobs which can be efficiently performed by a single person.

Having defined and packaged jobs, the evaluation of a system reaches that stage where the input of the human factors engineer is paramount--the development stage. The designer, at this point, knows what will be required of human beings. Knowledge of performance capabilities now comes into play. Occasionally, a system is designed without proper consideration for operator performance capabilities. The assumption is sometimes made that every operator holds an advanced technical degree, remains indefatigable after 20 hours on the job, can twist two knobs while reading three displays, press two buttons and simultaneously communicate with two supervisors. While manifesting such a high opinion of the operator may warm the cockles of one's heart, it is nonsupportive of the mission of the system.

Does this mean that you, as a designer, must be certain that individuals already exist who have the skill to perform the tasks you have analyzed?

(1) Yes. Turn to Page 22.
(2) No. Turn to Page 36.

From Page 53

(3) You're right again. Way to go!

As a review of some of these concepts, let's look at the total 'human system' involved in the 'man-machine system.' Okay, which of the following depicts the correct process involved in the 'human system?'

(1) Input, signal display, human processing, control response, output. Go to Page 62.
(2) Input, storage, selection, retention, output. Go to Page 95.
(3) Input, processing, output. Go to Page 88.
(4) Two of these answers are correct. Go to Page 78.

From Page 54

(2) Examining the etymology of a word may help you understand the subject but it is not essential. Return to Page 54.

From Page 21

(2) Your answer indicates that you feel that human values may more properly belong to some other domain. Not so. A human's ability to function effectively goes hand in hand with such values as safety. Return to Page 21.

From Page 26

(3) You're way off, 17 would be too many. We suggest you reread the supplement's section dealing with Miller's article. Go back to Page 26.

From Page 77

(4) Only one answer is correct here. Remember, you are dealing with the human system only. Go back to Page 77.

From Page 28

(1) There is more involved in information transmission than just the response. Return to Page 28.

From Page 53

(2) You'd better go back and reread the question. Isn't the nervous system important in terms of the output and input processes? Go back to Page 53.

From Page 85

(2) You have indicated that proper man-machine system design would have prevented many of the problems encountered during World War II. While proper man-machine system design is critical, it alone is not sufficient. Go back to Page 85.

From Page 30

(2) Right. It is a shame, isn't it? But things haven't improved very much, have they?

Human error still causes more system failures than design error, component unreliability, and lapses of quality control in manufacturing combined. In fact, in 1976 an investigation of the enhancement of Naval Sea Systems concluded that human-initiated malfunctions accounted for 50-70 percent of all failures of major weapons and space systems. This is not much less than the human-error rate of the Second World War.

A 1979 report on human factors engineering technology for ships concluded that Human Factors Engineering technology was not being adequately applied to ship system design. Without such requirements in the design of ships, the ship's personnel must use systems which are difficult, and in some cases, impossible to operate, control, maintain, monitor, and/or manage. The report cites three aircraft carrier accidents which could be associated with deficiencies in Human Factors Engineering. These deficiencies cost the Navy over $100 million and resulted in the loss of 207 lives.

In this report, eight carriers were visited and a list of human factors deficiencies was compiled. Now, take a guess. How many errors or deficiencies do you think were found?

(1) 1,280 were found. Turn to Page 8.
(2) 569 were found. Turn to Page 14.
(3) None were found. The carriers were perfect specimens of human engineering design. Turn to Page 22.

- -

From Page 47

(2) You say you'll use your 'common sense.' That might work sometimes, but as you'll see later, it also can get you into a lot of trouble. Return to Page 47.

- -

From Page 29

(2) High speed and safety don't usually go hand-in-hand on a highway. Who is your insurance agent? Go back to Page 29 and give it another try.

- -

From Page 36

(3) You indicated that revising mission requirements would be the first step if it were determined that man was incapable of performing a given task. This is incorrect. Changing mission requirements, in effect, results in reducing the overall capabilities of a system and should be a last resort. Go back to Page 36.

- -

From Page 55

(3) Ergonomics is the study of work, but its viewpoint is broader than economics. Go back to Page 55.

From Page 70

(2) C'mon, this isn't the 'brave new world.' Go back to Page 70.

From Page 65

(1) You too can make history, but we hope you've seen more than that in these first five lessons. Try again. Go back to Page 65.

From Page 26

(1) You're right again. Absolute judgments on a single visual dimension (hue) call for a maximum limit of seven plus two, or nine colors. This was illustrated in the table presented in the supplement, and it might be wise to refer back to the various totals given. Furthermore, where it is highly important to avoid errors, the signal capacity should be set below the maximum number, so as to allow a safety margin, or actually a margin of error.

The correct answer for this question was nine colors, because, for a single hue in the visual dimension, nine has been found to be accurate. Seventeen colors is correct only if judgments are based on size, brightness, and hue (thus more than one dimension).

It has been shown that man's ability to make judgments is far greater when a standard for comparisons is present than when absolute discriminations are required. The fact that our ability to make discriminations in relative judgment situations far exceeds our ability to make absolute discriminations has important design implications for a wide variety of jobs. The relevance of such information can be seen especially in jobs involving classification, grading of products, or quality control inspections. For example, the pilot who estimates his altitude visually is making an absolute judgment. In this, as well as other situations, it may be possible to redesign the pilot's task to increase the efficiency of responding; for instance, incorporating displays that involve a scene of the pilot's position relative to his surroundings. A more detailed discussion of displays will be presented in Lesson Nine.

Given the information presented in the last several pages, which of the following ways would you choose as a means of improving the altitude judgments required of the pilot?

(1) Tell the pilot to learn by trial and error. After all, experience is the best teacher. Go to Page 69.
(2) Provide a set of standard stimuli (in this case, possibly a set of assimilated views of how various landmarks appear at different altitudes) against which to compare the landscape to be judged. Go to Page 57.
(3) Have the pilot rely on information from other pilots flying at different altitudes. Go to Page 75.

From Page 54

(1) You think that the point is that since man realizes he can't get out of work, he tries to make it easier. That's correct.

The fact that man has not finished his study, nor outstripped his need to work is further evidenced by the existence of human engineering labs and related research facilities throughout the country (and the world)...

Eager figured that the study of work had something to do with his new job (although he's still not sure what), so he finished his snack and continued reading...

It is not certain when and where the study of work engineering as a scientific discipline began. It appears, though, that the major impetus to systematizing work was economics. It was the industrial revolution of the 19th Century which turned the study of work into a more pragmatic enterprise. At the beginning of the period several laws were enacted, and studies were conducted to investigate the relationship between productivity and workers' sex and age and their schedule of hours worked. Problems related to work content and design of working spaces and conditions were not investigated until later (because of a lack of standard values). However, as these problems became evident, research was initiated. A semblance of what is now called work study was in use by at least two large U.S. companies before World War II. It is widely recognized that an American, Frederick W. Taylor, 'the father of scientific management,' pioneered quantifying and measuring work and introduced work simplification techniques. Many of Taylor's contributions provide the basis for what is now called industrial engineering. The work elements which Taylor had precisely measured were further examined by Frank Gilbreth and his sociologist wife, Lillian. The main concern of this work was an economic one—using incentives (money) to increase productivity.

Another American involved in this field was Charles Bedaux. An American industrial consultant, he began studies early in this century to develop an objective system of work measurement which is a basis for much of that effort today. Realizing that workers were not alike in performance, he developed a rating measurement system on which to base bonus payments. Although not apparent at the time, Bedaux's studies laid the foundation for what was to evolve as an empirical basis for work measurement; that is, the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

(Go on to the next page)

From Page 84

You might begin wondering what the study of work has to do with Human Factors Engineering. What do you think of the following explanation?

Since man spends most of his time either working or thinking about work, the environment in which he works and the tools with which he works must be designed with him in mind. Sounds pretty good, doesn't it?

You can see that the work study approach has existed for many years. The acceptance of Taylor's 'scientific inquiries' and Gilbreth and Bedaux's work measurement are early examples of its impact on industry. But 'work study,' as these efforts became titled, was not fully developed until the latter part of the first quarter of the Twentieth Century as a management service sub-discipline of industrial engineering. World War II produced a new series of demands on work technology. With skilled craftsmen away fighting, unskilled laborers were required to produce quickly, effectively, and in large numbers. New weapons and more sophisticated weapons systems were also needed. Performance of existing systems was quite often less then satisfactory. Errors in bombing were greater than anticipated, and bombs often fell on the wrong cities. Aircraft losses were unacceptably high. Submarines equipped with sonar often attacked non-existent targets or marine life, and they often failed to find actual targets. The majority of these failures were directly attributable to human inefficiency rather than weapon system inadequacy.

The ideal way to prevent the problems encountered with weapon systems during World War II would have been:

(1) Through better training of personnel. Go to Page 91.
(2) Through better man-machine system design. Go to Page 79.
(3) Through better selection of personnel. Go to Page 92.
(4) All of the answers listed here are correct. Go to Page 63.

From Page 94

(2) That's only partially correct. Human Factors Engineering had indeed come of age, but other factors also contributed to the shift. Go back to Page 94.

From Page 96

(2) Now, do you really think this is the answer you want? If these were true, where would that put you? Even if all equipment everywhere were totally automated, man would still be necessary to program and maintain it. We think you were just testing us when you selected this answer. Therefore, you have three virture points taken away. Go back to Page 96 and try again.

From Page 56

(1) This is not really a physiological limitation, as such, nor is it true as far as processing limitations are concerned. Go back to Page 56.

From Page 58

(3) It's true that physiological processing limitations do affect a person's ability to function properly, but do you think this was a main cause for Eager's losses? Return to Page 58.

From Page 16

(3) 'Laborare' doesn't mean to study. This is a tough one. Go back to Page 16.

From Page 54

(3) Although the study of work may have started in Europe, America's contribution has been great. Go back to Page 54.

From Page 61

(3) Both answers aren't correct. Go back to Page 61.

From Page 77

(3) Good show! Looks like you've passed this lesson with flying colors.

Response mechanisms consist of the various muscle groups (including the vocal system) with which people can respond and manipulate their environment. Through the use of the muscles, man can move levers, press foot pedals, throw switches, in fact, execute a number of responses designed to control machines. If you are to predict the system's performance, much needs to be known about things such as the physiological speed and precision capabilities of the individual.

Well, so far you have reviewed a numer of key aspects of basic information processing, as well as noting some important processing capabilities or limitations of the human system.

Man receives input or stimuli from the environment, then must process this information by classifying and interpreting. Once this has been accomplished, man can respond to manipulate his environment. Thus, the process involved proceeds from input, through processing, and then to output.

Maybe this discussion can be aided by a quick look at just one way this process was applied in a practical sense by CPT Smart at the Human Engineering Lab. Take, for instance, a project Smart had recently been working on—cockpit controls and instrumentation. This project involved not only the proper arrangement and types of instrument gages on a panel (which is important in terms of input to the pilot), but also the types of controls, and their arrangement (which plays a key role in output). Thus, the HFE problem was not only to arrange the panel to optimize input, and thus processing speed and accuracy, but also, and equally important, to position controls to optimize the pilot's speed and accuracy of responding. These topics will be discussed in more detail in future lessons.

(Go on to the next page)

From Page 88

Congratulations, you have successfully completed another lesson in this HFE course. Your next lesson will be concerned with an overview of some important work that has been done in the human factors field. However, before you proceed with this lesson, let's take one last look at I. M. Eager and see how our hero has been faring.

Having consumed several pizzas and a couple of beers, Eager decided to 'call it a night' and head for home. CPT Smart and the remaining guests wished him good-bye as he began to amble slowly westward, deep in thought about the events of the evening.

Returning to his apartment, Eager flung himself on his bed to recuperate from the events of the evening. Maybe you should take a break, too, and we'll get together again when you're ready for Lesson 5. It is concerned with the history of Human Factors and related technology, or... 'Human Factors, This Is Your Life.' This lesson can be found on Page 71.

From Page 18

(2) Exactly right. The most important time to consider Human Factors is in the design stage of development. Operators and maintainers are, of course, concerned with human considerations, but not really with the regulations.

You will also examine human performance requirements, how to determine them, as well as the factors which affect them. You will learn the mechanics of conducting experiments, analyzing and interpreting data, conducting task analyses, etc. All of this will help lead you to becoming more proficient in your job. You'll be able to interpret and apply the standards and specifications of the human factors engineering community with knowledge and confidence.

Overriding all of these objectives is one which we mentioned earlier, but can't really over-emphasize. It's one without which this course would probably not exist. What do you think that objective is?

(1) To provide you with some key reference material. Go to Page 45.
(2) To provide you with the background necessary to do your job well. Go to Page 33.
(3) To provide you with the necessary vocabulary to talk to human factors specialists. Go to Page 38.
(4) To allow you to see where human factors engineering applications fit in the military. Go to Page 42.

From Page 96

(3) Nice try, but do you really think this is true? As long as man is inquisitive, we will continue to ask 'what if' or 'how long can we' questions, and technology and knowledge will increase. Return to Page 96.

From Page 34

(2) This approach was used and will be discussed later, but it wasn't the only one. Return to Page 34.

From Page 85

(1) You indicated that better training would have prevented many of the problems encountered in the utilization of weapons during World War II. Training is important, but it alone would not solve all the problems. Go back to Page 85.

From Page 64

(3) You feel that man's use of human factors information began with the organization of the Army-Air Force Aeromedical Lab in the mid 1940's. While that was one of the first military organizations devoted to Human Factors Engineering, it really doesn't mark the beginning of man's use of human factors information. Go back to Page 64.

From Page 20

(2) Your answer indicates that you feel human factors concerns alone should be used in the design process. You are incorrect. While these factors are critical, the design team must also be concerned with other parameters. Return to Page 20 and choose again.

From Page 58

(2) Selective attention did contribute to Eager's predicament, but it wasn't the only thing that affected his performance. Go back to Page 58.

From Page 85

(3) You indicated that proper personnel selection would have prevented many of the problems encountered during World War II. Selection of the right people certainly would have helped, but there's more to it than that. Go back to Page 85.

From Page 68

(4) Very good. You're right, all these statements are true.

Prior to World War II, the problem of man-machine interfacing was solved by the 'selection model.' A 'system' was designed and then a man was sought to operate within that system. But as machines became more sophisticated, their demands on human operation were greater. The devastating results of man's inability to interact successfully with much of the equipment designed for him led us to more detailed study and research into man's capabilities and limitations. Prior to World War II it was assumed (usually correctly) that a man could be found to perform whatever the system required. With the advance of technology, that situation changed. Some systems were just too sophisticated for man to operate. This fact necessitated the growth of the 'engineering model.' This model approaches the man-machine interface from a different perspective. Rather than developing a system and then thinking about the operator, this approach considers the requirements and capabilities of the operator in the design process itself.

This approach is evident in the advances made during the growth of aerospace technology. It is in this area that Human Factors Engineering displayed its first great triumph. The space flights of Gagarin, Titov, Shepard, Grissom, and others literally lifted the human factors specialist off the ground and into a position of respect, acceptance, and importance. The U.S. efforts to send a man to the moon succeeded only because man was not treated as a passenger who could adapt. Instead, the space vehicle system was developed with man in mind (the 'engineering model').

The third major era in human factors engineering history has been called the era of 'socio-technical systems.' As previously described, from the 1940's until the mid-1960's Human Factors had the military as its major arena. By the start of the 70's, Human Factors Engineering had broadened its focus to include problem areas other than those specifically related to the military. While military systems still held their own, human factors

(Go on to the next page)

From Page 93

specialists now talked about social issues, such as consumer problems, highway safety, pollution, etc. The shift has caused a change in emphasis from a study of the healthy male (the 'military man') to all kinds of people, young and old, healthy and handicapped. In addition to tanks, aircraft, and ships, the human factors engineer is also concerned with medical equipment, TV's and buses.

Why do you think this broadening of emphasis occurred?

(1) The human relations movement forced us to consider social problems from the human factors perspective. Go to Page 97.
(2) Human Factors Engineering had come of age and was going out on its own. Go to Page 85.
(3) We realized that the problem of man-machine interaction extended beyond military matters. Go to Page 72.
(4) All of these. Go to Page 55.

From Page 77

(2) This is wrong on two counts. First, selection is a retrieval process and an input process. For this sequence to be correct, it should have selection before and after storage. Second, storage and retention are the same thing. Return to Page 77.

From Page 16

(2) You indicated that you thought that the Latin word 'laborare' meant to do physical work. That's close, but not an exact translation. Go back to Page 16.

From Page 64

(2) You indicated that man's use of human factors information began during World War II. It was during World War II that the need for Human Factors Engineering became very obvious, but Human Factors were considered long before that. Go back to Page 64.

From Page 40

(3) Good show, you are absolutely accurate.

Human Factors Engineering follows the rules of scientific inquiry, but, as with all research (hard or soft), common sense is important in reaching conclusions from your investigations. Some people like to make a distinction between sciences such as physics and biology, and sciences such as psychology, sociology, and Human Factors Engineering. The former are referred to as 'hard' sciences because they can more accurately measure the phenomena with which they are concerned. For example, a chemist can measure the amounts of his chemicals as precisely as needed if his instruments are reliable. However, no chemist has tried to measure the amount of hydrochloric acid in a beaker while the acid was tired, or sick, or...you get the idea. Human Factors Engineering is often called a 'soft' science due to the difficulty of quantifying man's human attributes. But this doesn't mean that the data gathered are unimportant or unusable. In fact, this is just what I. M. Eager was told by his buddy during a rather heated discussion of that subject.

You see, the first night he was at his new command, I. M. Eager met a friend from his college days. His friend, Captain B. Smart, invited I. M. to a friendly bridge game. While at the game, Eager was griping about his new 'common sense' job. Since B. Smart had some experience in the field, he started to set Eager straight.

Smart explained to I. M. that ever since man has had tools and equipment, he has constantly improved on them, trying to make them more capable and efficient. During most of man's history, he and his tools have managed to keep pace with one another's development. Only since World War II, however, has man lost ground in this battle. Technological development since that time has been so rapid and so radical that it seems that before man has time to adapt to one concept, another innovation comes along. Much of this rapid advance in the complexity of technology can be laid on the doorstep of the computer age. But it is essentially the same model of man, albeit broadened in his background by the advantages of technology, that must continue to adapt and cope.

Now these rapid changes have caused many problems. But if we examine these problems, we'll find a common thread running throughout. Which of the options listed below do you think contains that common thread?

(1) Human errors are extensive. Turn to Page 21.
(2) All equipment should be totally automated. Turn to Page 86.
(3) Technology has finally reached its peak. Turn to Page 90.

From Page 9

(3) You will be asking this question, but only after you know the requirements placed upon the human. Go back to Page 9.

From Page 26

(2) Your answer is incorrect in terms of maximum number of categories. We suggest you reread the section in the supplement on Miller's article. Go back to Page 26.

From Page 94

(1) That's only partially correct. The humanistic (human relations) movement and its emphasis on improving conditions at work did indeed contribute to the broadening of the human factors discipline, but there was more contributing to this shift. Go back to Page 94.

From Page 65

(4) Exactly right. We hope that this overview has shown you that HFE is important and that your input is important in its implementation.

The next several topics will explain man's capabilities and limitations as well as performance requirements and how they're derived. If you haven't seen how this course is applicable to your job, these next few lessons should make it obvious.

From Page 55

(1) Ergonomics is concerned with work, but this answer limits its coverage. Go back to Page 55.

From Page 65

(2) You have been shown some tragic results when HFE principles are neglected, but there's more than that. Go back to Page 65.

From Page 47

(3) No! We hope you're kidding. Return to Page 47.

From Page 61

(4) One of these answers is correct. Go back to Page 61.

From Page 71

(3) Smart was making selective attention the key to Eager's losses, but he did nothing to negate Eager's ability to attend selectively. Return to Page 71.

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